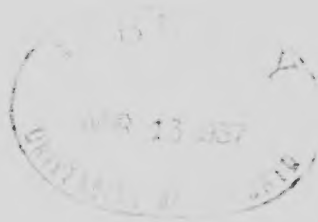


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**No. 95: LANTERN EXPERIMENTS ON REACTIONS IN
NON-HOMOGENEOUS SYSTEMS, BY FRANK B. KENRICK**

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LANTERN EXPERIMENTS ON REACTIONS IN NON-HOMOGENEOUS SYSTEMS¹

BY FRANK B. KENRICK

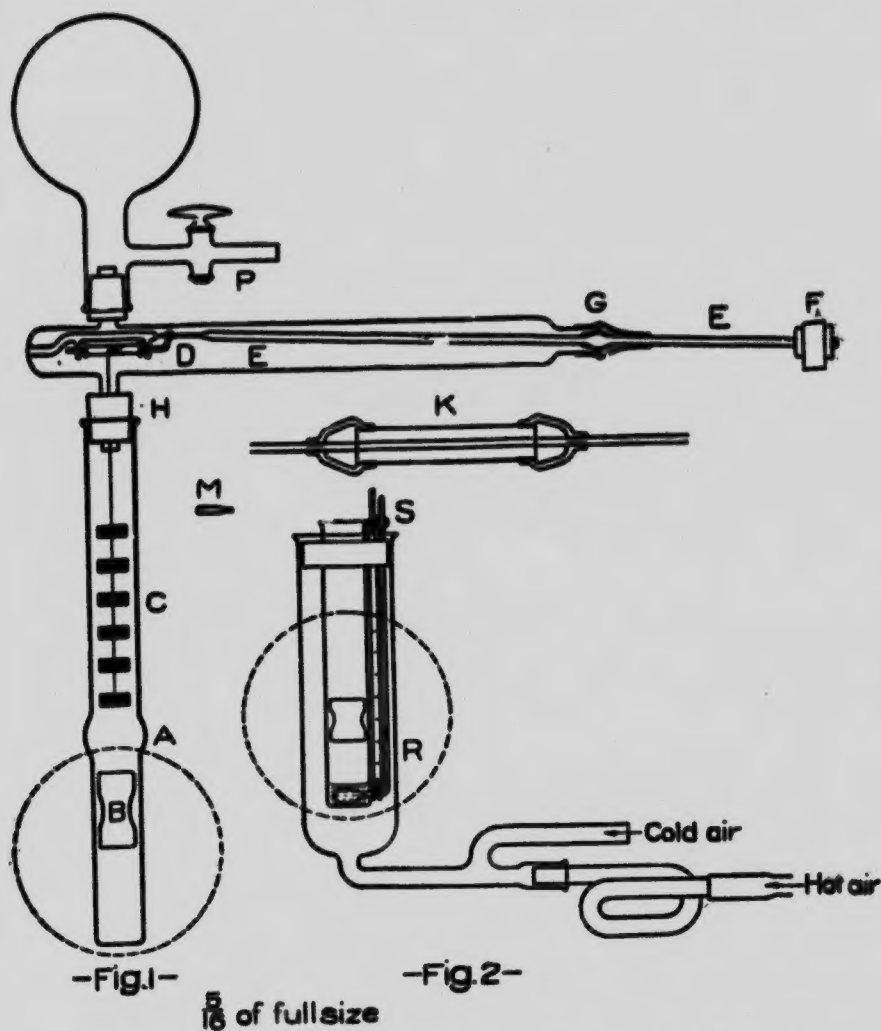
The use of graphs for expressing experimental relations has done much to simplify the teaching of general chemistry. A good diagram not only gives a concrete picture of a relation abstracted from tables of numbers but possesses also a peculiar fascination of its own for the average mind. A research student experiences a feeling of elation over his first experimental graph that is rivalled only by the sense of proprietorship of the organic chemist towards his first "new body." But in this very fascination there is a pedagogical danger. As the student's enthusiasm for the diagrams increases his interest in the troublesome chemicals often wanes; he begins to talk of melts moving along curves as if they were baseballs and to think of common salt existing in "fields" instead of in the sea.

To offset these dangers it has become the custom to draw diagrams of pistons and cylinders alongside the graphs, in the hope of keeping the balance between experiment and representation. With the idea of making these conventional cylinders and pistons more realistic the writer has used actual tubes containing the chemicals which may be thrown on the screen as working models.

The main difficulty in these experiments is in making an air-tight frictionless joint between the piston and cylinder. The only packing that the writer has found practicable is mercury, and since the leakage is prevented only by surface tension the pressures must be limited to comparatively small values. The four following experiments illustrate the use that may be made of these models.

¹ These experiments were shown for the first time at the Washington meeting of the American Chemical Society, December, 1911, in a lecture by Mr. H. E. Howe and the writer. The excellent Bausch & Lomb Convertible Balopticon was used in all the experiments; the arrangement of apparatus described in Nos. 5 and 6 applies particularly to this lantern.

1. *Boyle's Law*.—*A* is the cylinder tube (Fig. 1) in which the piston *B* fits loosely but closely. Both *A* and *B* are



flattened at the bottom for appearance sake. *C* is a string of lead weights (10 grams each), hung on a piece of cotton thread, the upper end of which is wound round the glass

winch *D*. The point of the rod *E* fits loosely into the little ring on the handle of the winch, which may be turned by moving the weight *F* in a small circle, there being a sufficient play at *G* to allow a slight side motion.

The apparatus is all put together with the exception of the joint *H*. The tube and piston are thoroughly cleaned and dried and about 7 mm of mercury is poured into *A*. A little bulb, *M*, open at one end and containing air, is dropped in and then the piston is inserted and pushed right down until enough mercury has been squeezed up to fill the waist. After connecting at *H* the apparatus is exhausted through *P* by an air-pump (a filter-pump is hardly sufficient). The air contained in the little bulb gradually expands and forces the piston to the weights. If one weight is not sufficient to balance the pressure when the piston is at the edge of the field of the lantern, shown by the dotted line, the weights are cautiously raised till the piston reaches the expansion in the cylinder, when a few bubbles of air may be allowed to escape past the seal.

When the weights are lowered the piston should go down smoothly, a definite, but decreasing, distance for each additional weight. If it sticks it means that either the tube or mercury is dirty. A well selected piston of the dimensions shown will support a weight of 200 grams, without the seal giving way.

A few points may be noted in regard to making the apparatus. A length of tube is selected first for the cylinder by running a pair of calipers over the stock of glass. The exact size is less important than uniformity of bore. In choosing the piece for the piston it will generally be found that if the end of a stick of glass fits approximately, there will be one piece in the stick of the right size. A number of pieces about three inches long should be corked at one end and dropped into the closed cylinder. One that falls slowly as the air escapes and shows no tendency to stick, even when turned through various angles, should be chosen. In making the waist in the piston a rod should be sealed through the

tube as shown in Fig. 1, *K* and the whole rotated in a small hot flame. In this way the two ends are kept exactly concentric.

The lead weights should be painted with melted sealing-wax, otherwise they are sure to become amalgamated by the mercury and the mobility of the seal is spoiled. They may be strung on a thread, in which knots are tied at intervals, and made fast by pressing the lead round the thread with a pointed tool. A little hook on the barrel of the winch catches a loop in the end of the thread, which can be poked up through the tube at *H*. The weight *F*—a cork with a strip of lead round it—prevents the winch from unwinding. The rubber joints may be made tight with tap-grease.

When once set up the apparatus may be kept for a week or more ready for use, but requires occasional re-exhausting.

2. *Vapor Pressure*.—The apparatus is similar to that used in Exp. 1. The little bulb, *M*, is filled completely with freshly boiled water (which has just the right vapor pressure for the apparatus) and mercury is squeezed into the seal as in Exp. 1. In exhausting the apparatus water vapor should be allowed to bubble through the seal at the expansion until about half the water has evaporated out of the bulb, so as to get rid of the small quantity of air always left in the corners. If the water is not freshly boiled it is apt to flow out of the bulb on exhausting, and the bubbling past the seal becomes too violent and uncontrollable.

The piston should go smoothly up and down on lifting or adding one extra weight. By gently warming the tube by the hand or by a small flame more weights are lifted.

When freshly filled this apparatus works admirably, but after a day or so the piston is apt to stick slightly at the position in which it has been left. The writer has found it better to rub out the cylinder with a *slightly* oily cloth. The water vapor then always condenses on the mercury and not on the sides of the glass, and if the piston is left down when not in use the sticking is avoided.

3. *Vapor Pressure and Temperature*.—Several very in-

structive experiments may be made at atmospheric pressure with a simpler form of apparatus. See Fig. 2. The cylinder and piston may be made from two carefully selected test tubes, though closeness of fit is not so necessary as in the previous experiments. A bulb about the size of a pea on the end of a thin-walled capillary tube sealed through the cylinder near the bottom serves as an air-thermometer, the temperature being registered by the height of a drop of mercury, *R*. The upper end of the thermometer is protected from breakage by the hook of glass *S*, which also serves to hold the scale, made by drawing out a microscope slide and marking the figures with india ink.

Enough alcohol, or other liquid, to cover the thermometer bulb is poured into the cylinder without wetting the sides. By holding the piston about half way out of the top of the cylinder mercury may be poured into the seal. If the tube is then slightly inclined the piston may be pushed slowly down to the alcohol while the air bubbles up through the mercury. A small bubble of air should be left to prevent superheating. The top of the piston must be slightly turned in, to prevent the mercury bubbling over into the hollow of the piston.

The cylinder is hung loosely in a larger thin-walled tube, 4 cm in diameter, as shown in the diagram. The temperature can be slowly raised or lowered by a current of air, the heat being conveniently supplied by a heated copper tube, as shown, attached to the glass by asbestos paper. On raising the temperature to a certain point the piston rises; on cooling a few degrees it drops back. The thermometer scale need be graduated only very roughly as long as the 78 mark corresponds to the temperature at which the piston goes up. The superheating of a liquid may be shown, if, during the heating, the piston be pushed down several times so that the alcohol vapor bubbling through the seal carries out the remaining air. After now completely condensing the vapor the liquid may be heated well over the boiling point, until the piston is suddenly driven violently up to the top of the cylinder.

4. *Decomposition Temperature.*—The decomposition of powdered calcium chloride ammonia may be shown in the same apparatus as used in 3, but to get a reasonably sharp temperature the air must be expelled from the powder by pushing the piston down several times during the heating. This, however, must be done at the time of showing the experiment; for if the tube is once allowed to cool after the air is expelled the mercury will be sucked down from the seal into the powder.

It may be mentioned that in the last two experiments the thermometer must be inside the cylinder, because otherwise, unless the heating is very gradual—and this takes too long for a lecture experiment—the thermometer would become heated much more rapidly than the liquid. The use of a water bath to supply the heat is excluded by the refraction of the water. The apparatus is, no doubt, capable of further application, but it may be noted that subliming solids condense on the glass and cause sticking.

5. *Delayed Reactions.*—In connection with the superheating of the alcohol in Exp. 3, the analogy between the crystallization of a supersaturated solution on nuclei and the reduction of silver salts in photographic development may be shown as follows. The experiments have nothing to do with pistons and cylinders but may properly be described under the title of this article.

After placing a crystallizing dish in the vertical attachment of the lantern the bottom of the dish is written on with a crystal of copper sulphate. Although nothing is visible on the screen the writing may be "developed" by pouring into the dish a supersaturated solution of copper sulphate, made by cooling a solution saturated with this salt at 45°C to the ordinary temperature.

The experiment may be varied to show the meaninglessness of the use of the term "saturated solution" without specifying the substance in respect to which it is saturated. "Copper chloride" for example may be written on the dish with an alcoholic solution of copper chloride and allowed to dry, while "copper sulphate" is scratched over it with a

crystal of copper sulphate. On developing with the copper sulphate solution the words "copper chloride" are replaced by "copper sulphate."

It may not be generally realized that a solid projection lantern serves as an excellent lecture-room camera. In fact, the whole process of exposure, development and projection of the negative may be carried out in the lantern in less than three minutes. The lantern is focussed for the solid projection of a crystallizing dish, an orange screen¹ and an opaque card being placed between the projection cabinet and the lamp. A second lantern is arranged to give a "spot-light" on the screen in the exact position of the image of the crystallizing dish. A disc of developing paper (special velox) is placed in the dish and held down by a ring of glass. The subject to be photographed stands, or is placed, against the screen in the spot-light. After a sufficient exposure—about two minutes if the lantern is not too far from the screen—the spot-light is turned off and the opaque card drawn out of the other lantern, showing the dish and plain paper on the screen. A few seconds later the developer should be squirted into the dish through the peep-hole in the lantern box, and then the hypo solution, as soon as the image appears on the screen.

6. *Arrangement of Lantern.*—In the projection of glass apparatus the best results are obtained by placing the object in parallel light close *behind* the condensing lens *A*, Fig. 3. A convenient arrangement for the lantern for general purposes is shown in the same diagram. The two large mirrors on the stand *B* in front of the lantern rectify the image and throw it on a screen on the right hand wall of the lecture room. By reversing the positions of the mirrors *C* and *D*

¹ I am indebted to Professor A. H. Abbott, University of Toronto, for the following receipt for an excellent light screen. Three photographic plates are washed in hypo and dyed respectively with quinoline yellow, Indian yellow and methyl violet. The first two should be dyed as dark as possible, but the third should be only a faint violet shade. The three plates are used together.

in the vertical and solid projection attachments¹ the images from these are also thrown to the right. The "Schlieren" apparatus (see footnote, Exp. 3, *b*, preceding article) may be used, at the same time arranging the lenses to the left of the lantern. By simply sliding the large mirrors *B* out of the way the image

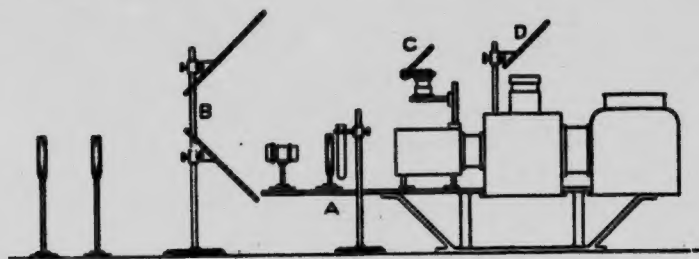


Fig. 3

is thrown on the left wall of the lecture room. The lantern may be placed well to the right of the lecture table, thus giving the necessary distance between screen and lantern required by the "Schlieren" apparatus.

*University of Toronto, Chemical Laboratory,
March, 1912*

¹ Messrs. Bausch & Lomb will supply their Convertible Balconicon with the slight modifications required for reversing the position of the mirror *D* and detaching the lens *A* from the vertical attachments.

